REPORT No. 346

WATER PRESSURE DISTRIBUTION ON A FLYING BOAT HULL

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SUMMARY

The investigation reported herein was conducted by the National Advisory Committee for Aeronautics at the request of the Bureau of Aeronautics, Navy Department. This is the third in a series of investigations of the water pressures on seaplane floats and hulls, and completes the present program. It consisted of determining the water pressures and accelerations on a Curtiss H–16 flying boat during landing and taxying maneuvers in smooth and rough water.

The results show that the greatest water pressures occur near the keel at the main step, where the maximum pressure is approximately 15 pounds per square inch. From this point maximum pressures decrease in magnitude toward the bow and chine. Pressures of approximately 11 pounds per square inch were experienced at the keel slightly forward of the middle of the forebody when taking off in rough water. The area of the forebody subjected to considerable pressure is roughly a triangle having its base at the step and its apex on the keel at the load water line forward. On the bottom between steps, a maximum pressure of 8 pounds per square inch is nearly uniform. A vertical acceleration of 4.7g is the greatest value encountered in landings, and is considerably greater than any other value recorded. It was found that 3g is approximately the maximum to be expected in take-offs in rough water, and that this value was exceeded during only a few landings. A longitudinal acceleration of 0.9g was once attained in a landing in rough water and 0.7g is not unusual for take-offs in rough water. The maximum lateral acceleration attained in cross-wind landings is approximately 0.5g. The results show that the landing loads were usually borne by an area near the main step, and that rough water may cause large loads to be applied near the middle of the forebody.

INTRODUCTION

When considering the water reaction on a seaplane float, the designer should know the magnitude of the total water force, the manner in which the water load is distributed, and the magnitude of the maximum local pressures on all parts of the float bottom. The latter item may be a separate consideration because high local pressures are not necessarily associated with large total loads. For this reason data on the distribution of maximum pressures should be correlated with total loads if possible. This has been kept in mind during a series of water-pressure distribution investigations requested by the Bureau of Aeronautics, Navy Department, and conducted by the Langley Memorial Aeronautical Laboratory, at Langley Field, Va.

The investigation reported herein was conducted on a boat type seaplane. It is the third in the series of investigations and completes the present program. The two previous investigations were conducted on a single-float and a twin-float seaplane, respectively, and have been previously reported. (References 1 and 2.)

An H–16 flying boat was used for these tests. Water pressures at 15 stations in the hull bottom were measured simultaneously during numerous taxying and landing maneuvers on smooth and rough water. Accelerations along the three reference axes of the seaplane were also measured. Measurements of the longitudinal angle of the hull, the air speed and the average wind velocity during tests were made for the purpose of describing and classifying maneuvers.

The measured pressures and accelerations are tabulated in this report. The distribution of maximum pressures is shown by tables and curves, and the relation between local pressures and total water reactions is explained from a study of the records obtained. The results are compared with those obtained in previous investigations. From a correlation of pressure and acceleration records, approximate load distributions for two critical conditions are derived.

APPARATUS AND METHOD

Apparatus.—The H–16 flying boat (fig. 1) is a twin-engined biplane weighing about 10,500 pounds fully loaded. During the tests it was loaded to approximately 10,000 pounds and was found to land normally at a speed of about 50 m. p. h. The lines of the hull are shown in Figure 2. It is constructed of wood. The side sponsons, or fins, as they are called, extend the bottom lines considerably beyond the true chines. For convenience, however, the fin edges are called chines in this report. It may be observed that the keel line is a continuous curve, and that the steps are formed by additional surfaces built on the main bottom. The lines are such that the planing surface has a considerable positive angle of inclination to the horizontal when the hull is level. The angle of incidence of the wings also is positive, the angle being 4° for both wings.

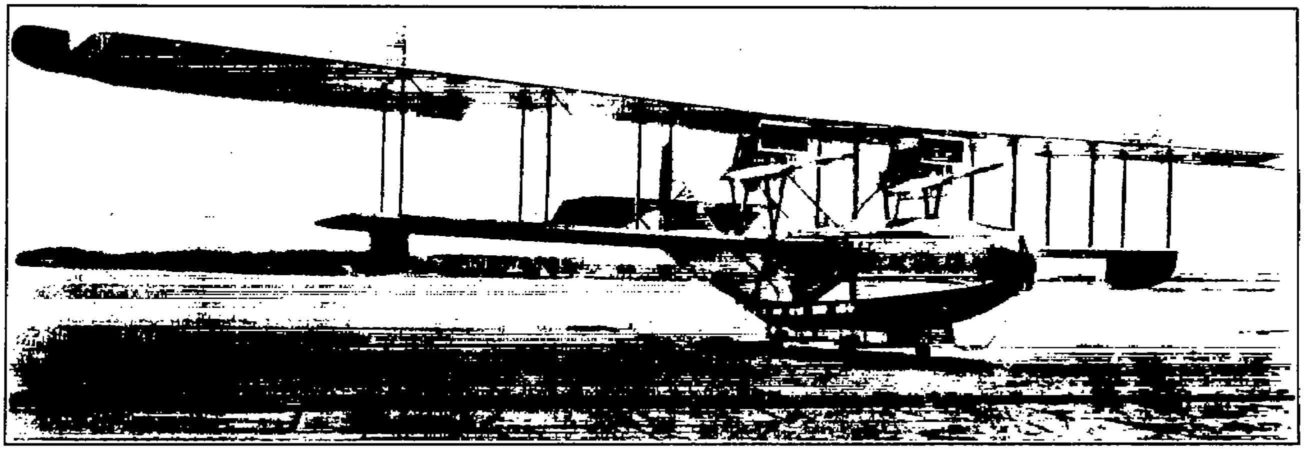

FIGURE 1.—The H-16 flying boat

The research equipment consisted of the following:

1. Water-pressure apparatus.
2. Three single-component recording accelerometers.
3. A four-element plunger-type accelerometer.
4. Two recording manometers.
5. A swiveling Pitot-static air-speed head.
6. A float angle observer.
7. A motor-type electric timer.

1. The water-pressure apparatus is fully described in reference 1. Water pressures exceeded or not exceeded within a limited range are indicated by a number of water-pressure units installed in the float bottom. Pneumatic pressure, which can be readily varied, is applied to the inner ends of four pistons in each unit. The inner ends of these pistons have equal areas, and the external ends, which are subjected to water pressure, have unequal areas. Consequently, each piston responds to a different water pressure at a given pneumatic pressure, and by changing this pressure the recording range can be varied as desired. The movement of each piston closes an electrical circuit, and the four pistons in each unit are connected through resistances in parallel to a recording unit on a multiple recorder. The recording unit is a solenoid which deflects a light beam by steps when action of the pistons varies the current. A record of the motion of the light beam in each of the several units attached to the multiple recorder is made on a rotating photographic film. Fifteen of these water-pressure units were installed in the left side of the hull bottom. (Fig. 3.)

2. The N. A. C. A. single-component recording accelerometer is described in reference 3. The components of acceleration along the X, Y, and Z axes of the seaplane were measured with three of these instruments rigidly mounted on main structural members inside the hull. The instruments used to record vertical and longitudinal accelerations were located about 1 foot below the $C.\ G.$ The one used to record lateral accelerations was mounted about 3 feet to the rear of the other two, and was used during comparatively few runs.

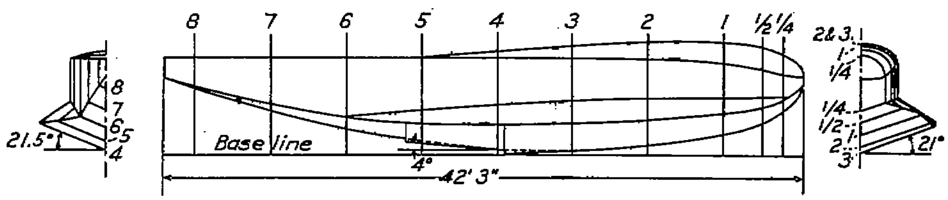

FIGURE 2.—Hull lines of the H-16

3. The 4-element plunger-type accelerometer is described in reference 2. It is similar in principle to the

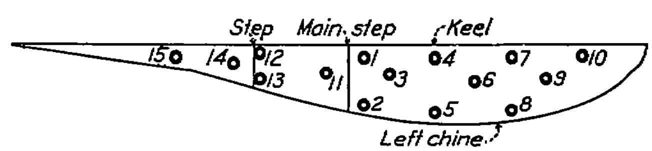

FIGURE 3.—One-half of the bottom plan of the H-16 hull showing locations of pressure stations

Zahm type of instrument, in that it makes use of plungers acting against coiled springs, which allow the plungers to move when certain accelerations are exceeded. Four such plungers, adjusted to respond to accelerations ranging from $1.5g$ to $6.9g$, were contained in one unit. These plungers were electrically connected in the same manner as the pistons of a water-pressure unit, and when in use, the instrument was connected to the water-pressure recorder in place of one of the water-pressure units. Accelerations of the hull bottom in two regions of high pressure were measured at different times during the tests. The accelerometer was first mounted about 4 feet forward of the main step, and was later moved to a position near the middle of the forebody. It was not placed closer to the main step because of the double bottom in that region. The records obtained with this instrument were used primarily to indicate the acceleration which should be used in the computation of a correction to the recorded maximum pressures for the effect of acceleration of the pressure units.

4. The N. A. C. A. recording manometer is described in reference 4 as the recording element of the N. A. C. A. recording air-speed meter. Two 2-pressure cell instruments of this type were used. Three of the 4 recording elements thus provided were used to measure pneumatic pressures applied to water-pressure units as described above. The fourth element was used to record air speed.

5. A swiveling Pitot-static air-speed head was mounted on an outboard wing strut for the measurement of air speed. It was connected to the recording element mentioned above.

6. The float-angle observer is a small motor-driven motion-picture camera used to photograph the shore or horizon line parallel to the path of the seaplane. The angle of the longitudinal axis of the hull with respect to the horizontal was recorded by this means.

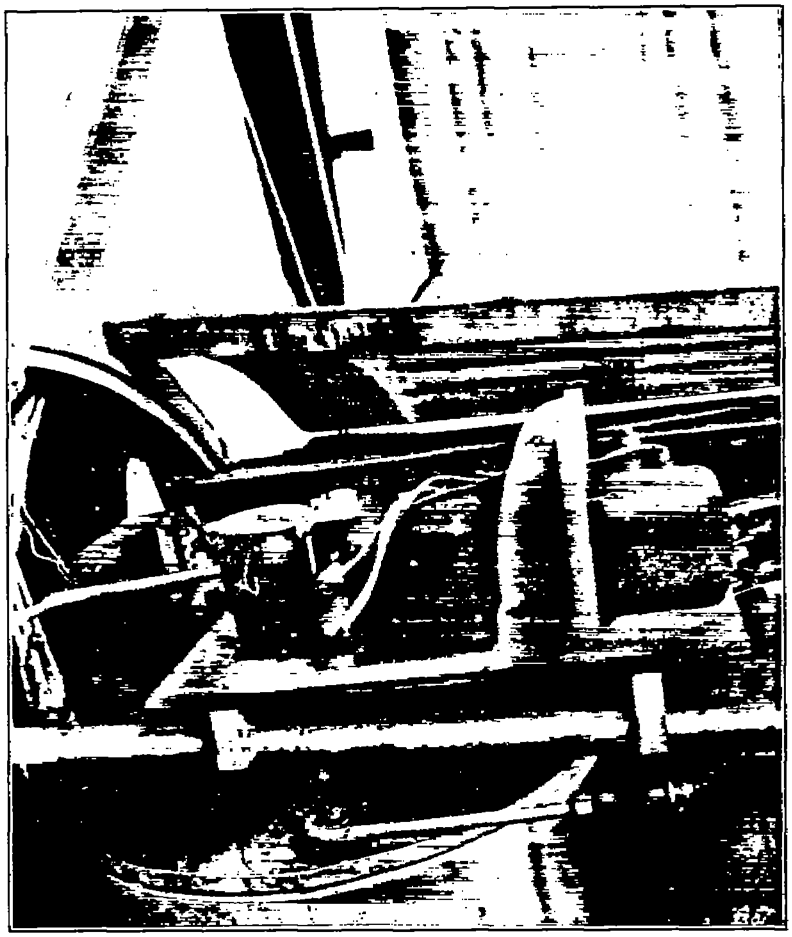

FIGURE 4.—Accelerometers mounted for the recording of vertical and longitudinal accelerations

7. An N. A. C. A. motor-type electric timer, similar to the chronometric timer described in reference 5, was used to synchronize all the above-mentioned records at 1-second intervals.

Parts of the instrument installation are shown in Figures 4 and 5. Figure 4 shows the accelerometers used for recording vertical and longitudinal accelerations. Figure 5 is a view of the observer's compartment, showing control switches, the hand pump, sight gages and recording instruments of the pneumatic system, and the electric timer. At the rear of this compartment, a dark room was constructed for the purpose of changing photographic film records in flight. This made it possible to make a large number of runs during one flight.

Method.—With the instruments described above, continuous synchronized records of the water pressures, accelerations, air speed, and float angle were obtained. The duration of the records was usually about six or eight seconds for all except the water-pressure record. This record included only a part of the above period, usually about two or three seconds. In addition to the above records, the average wind velocity during tests was measured with an anemometer from a boat standing by near the seaplane. Readings were taken over periods of two to five minute intervals during the flights.

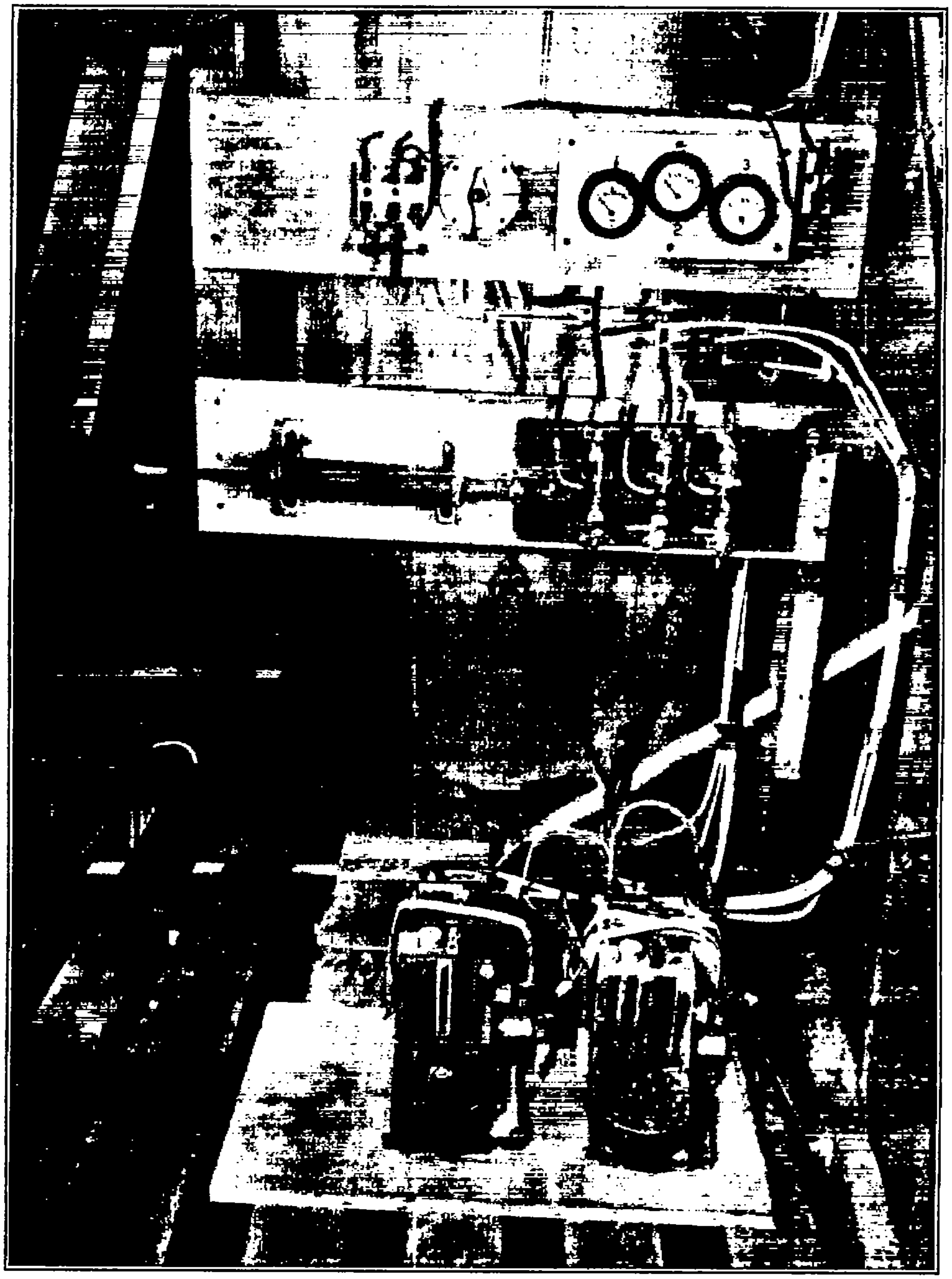

FIGURE 5.—Instruments and controls in the observer's compartment

Records were taken while taxying at various speeds, while getting off and during numerous landings. A large part of the test work was carried out in rough water. Runs were made in sharp-crested waves up to 3 feet high accompanied by wind or by wind and tide. In the latter case, the water was usually choppy. Several landings and take-offs also were made in swells varying in height from 1 to 5 feet.

An attempt to take off perpendicular to swells 3 to 5 feet high in a negligible wind failed. At a speed of 35 m. p. h., the boat was pitched several feet into the air and fell off slightly on one wing. Take-offs were then made parallel with the swells without difficulty. No serious trouble was experienced in making landings perpendicular to these waves. A sharp lateral blow on the stern of the hull was felt in one such landing, and later a large hole appeared in the bottom of a wing tip float after a particularly rough landing.

Several take-offs and landings were made in sharp-crested waves about 3 feet high without difficulty or damage to the seaplane. The hull was subjected to an extremely severe pounding by these waves, however, particularly during the take-off runs. The crew of the seaplane was probably more impressed by the severity of these impacts than those encountered during any other conditions.

The only parts of the seaplane damaged during the flights were the two wing tip floats. One of these was damaged during a landing in rough water as mentioned above. The other was completely demolished in a cross-wind landing. In this landing, the leeward float suffered the damage and the wing tip submerged, causing the seaplane to execute a "ground loop" about the submerged tip. This happened in a 10 m. p. h. wind and waves from 15 to 20 inches high. It is worthy of note that the seaplane took off and landed in smooth water without difficulty.

PRECISION

The maximum water pressures as given in the summarized data and pressure distribution curves are considered, as in reference 2, to be accurate within ±10 per cent.

The accuracy of the air-speed recorder is believed to be within ±2 per cent. There is, however, a possibility that the recorded speed may be consistently low due to disturbed flow in the vicinity of the Pitot-static head. This error probably varies from a negligible amount at low angles of attack to less than 8 per cent at high angles of attack. The air speeds given in this report, therefore, may be from 6 to 10 per cent low.

The average wind velocity as measured with an anemometer at intervals during flights may be considerably different than the velocity at a given instant, because of unsteadiness of the wind. The error caused by such variations is considered to be within ±3 m. p. h.

The recorded values of longitudinal float angles are considered to be accurate within ±½°.

The accuracy of the recording accelerometers was affected by structural vibrations. The instruments were lightly damped to allow them to record accelerations of short period with the result that they responded to high-frequency vibrations of the structure. The amplitude of these vibrations increased with engine speed, although the period remained at about one-fortieth second. It was necessary, therefore, to read the mean values indicated by the record lines, and to disregard peak accelerations with a period as short as that corresponding to structural vibrations. Sharp vertical and longitudinal accelerations were most affected because their periods were sometimes only slightly longer than the period of the structure. Lateral accelerations lasted longer. The accuracy of the recorded accelerations is considered to be within $\pm 0.3g$ for the vertical, $\pm 0.2g$ for the longitudinal, and $\pm 0.1g$ for the lateral component.

The limits given by the float-bottom accelerometer are believed to be very accurate except for the $3.2g$ limit, which is possibly in error by $\pm 0.2g$ due to friction of the plunger.

RESULTS

Pressures.—The water-pressure data recorded during each run are given in Table I. Maximum accelerations recorded simultaneously with water pressures are also given in this table. The maneuver executed in each run is described as to air speed, longitudinal angle of the seaplane, average wind velocity, and condition of the water's surface.

True maximum pressures at each station are given in Tables II (*a*) and II (*b*). These tables give the five highest pressures at each station for landings and for taxying maneuvers. These values are corrected mean pressures taken from the highest limits given in Table I. The correction is one-fourth pound per square inch, which is added to the recorded limits to counteract the effect of acceleration of the water-pressure units on the recorded pressures. This correction corresponds to an acceleration of $4g$ (reference 1), which the float-bottom accelerometer shows is a fair maximum value. The true pressure is considered to be the mean of the corrected limits unless there is no value given for an upper limit of pressure not exceeded. In the latter case, the true pressure is considered to be greater than the corrected limit of pressure exceeded by one-half pound per square inch. This assumed value is based on a consideration of the small number of times these highest pressures were exceeded, the pressures actually established at other stations and the extremely short duration of the highest pressures.

The maximum pressure at each station for each condition as given in Tables II (*a*) and II (*b*) is used in plotting the two sets of curves of Figures 6 and 7. In these figures, estimated pressures are given for a few stations at which maximum pressures were not definitely established because they were always less than the minimum pressures, which the units at these stations were set to record. Thus, the pressure at stations 5, 9, and 10 of Figure 6, and station 5 of Figure 7, is estimated at 3 pounds per square inch, and is considered to be negligible at stations 8 and 15 in both cases and at stations 12 and 14 in Figure 7. These values are based on a consideration of pressure limits not exceeded at these stations and pressures established at surrounding stations.

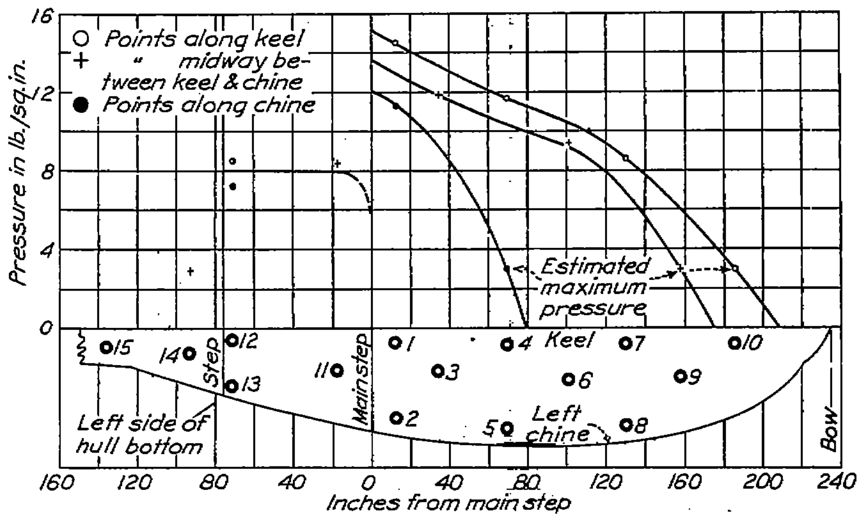

FIGURE 6.—Distribution of maximum water pressures on the H-16 hull in landings

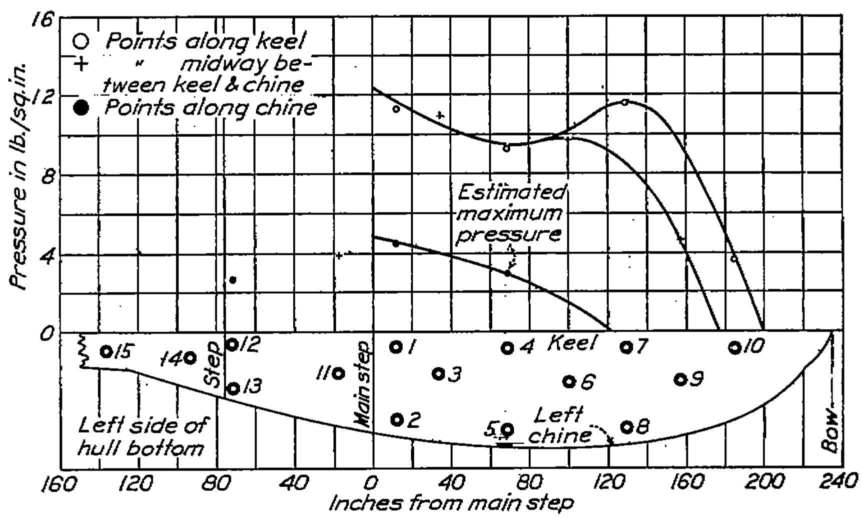

FIGURE 7.—Distribution of maximum water pressures on the H-16 hull in taxying

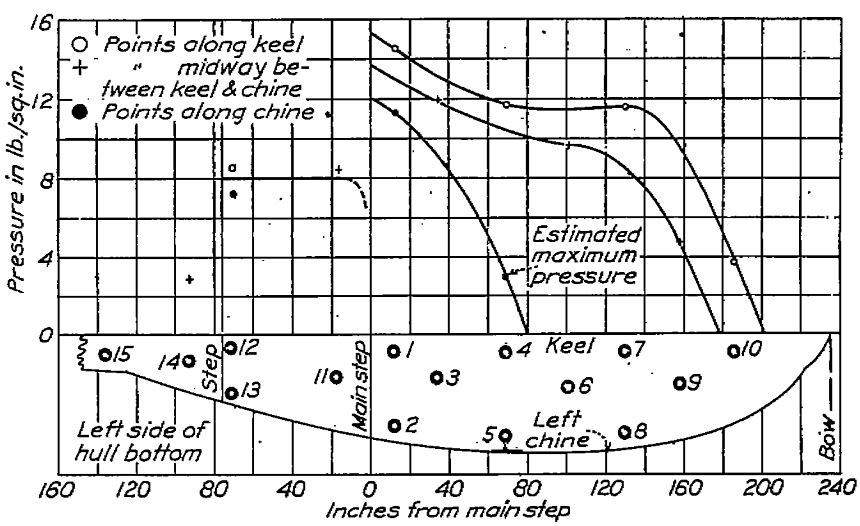

FIGURE 8.—Distribution of maximum water pressures on the H-16 hull for all conditions of landing and taxying

The curves of Figure 6 show the distribution of maximum pressures for landings and those in Figure 7 for taxying maneuvers. In Figure 8, the two conditions are combined to show the distribution of maximum pressures for all conditions. Figure 6 shows that the principal landing shocks, with pressures ranging from 11 to 15 pounds per square inch, are borne on an area that includes stations 1, 2, 3, and 4; and that somewhat smaller pressures may be experienced at stations 6 and 7 in the middle of the forebody, and at stations 11, 12, and 13 abaft the main step. It is shown in Table I, however, that pressures at stations 6 and 7 of the magnitude shown in Figure 6 are unusual in landings. Figure 7 shows that large pressures may occur quite generally in take-offs over the forebody from the main step forward to about two-thirds the distance to the bow. It should be noted, however, that high pressures forward only occur close to the keel and not at the chine. In general, as Table I shows, pressures of approximately 10 pounds per square inch are very likely to occur near the keel as far forward as stations 6 and 7 during take-offs. A summation of all the data shows that the portion of the forebody subject to considerable pressure is roughly triangular in shape. The base of this triangle is the main step, and the apex is at the keel forward near station 10, which is close to the load water line. From the step at the keel, pressures decrease in magnitude toward the bow, and from the keel they decrease toward the chine. Maximum pressures of about 8 pounds per square inch are distributed uniformly over the area between the main and second steps.

The pressure distribution curves show the magnitude of the maximum local pressure likely to be experienced on any part of the hull bottom. They do not indicate, however, the manner in which pressure is distributed at any given instant, or a specific relation between local pressures and total water reactions. These two questions can be answered in a general way by a further analysis of the pressure records with respect to the time at which high pressures occur at the various stations during a maneuver and by studying the relation between acceleration and pressure records. It can be seen at once, however, that the total water reaction is likely to be borne on a small part of the total bottom area when local pressures are of the magnitude found in this investigation. For instance, a pressure of 10 pounds per square inch acting on an area of 20 square feet would exert a total water reaction equal to nearly three times the weight of the seaplane; and 20 square feet is approximately 15 per cent of the projected area of the hull bottom between the main step and the forward load water line.

An illustration of the rapidity and magnitude of pressure variations is given in Figures 9 and 10. Figure 9 is a reproduction of pressure and vertical acceleration records obtained in an exceptionally hard, but otherwise normal landing made with the pressure units set to record fairly high pressures. Figure 10 is a reproduction of similar records obtained in a landing made with the pressure units adjusted to record small pressures. The acceleration records are continuous, but the water pressure records, due to the system of recording, only show the magnitude of certain pressures exceeded or not exceeded. The pressure record for each station is a horizontal line, which is displaced up or down by steps when the water pressure varies through the recording range of the instrument at this station.

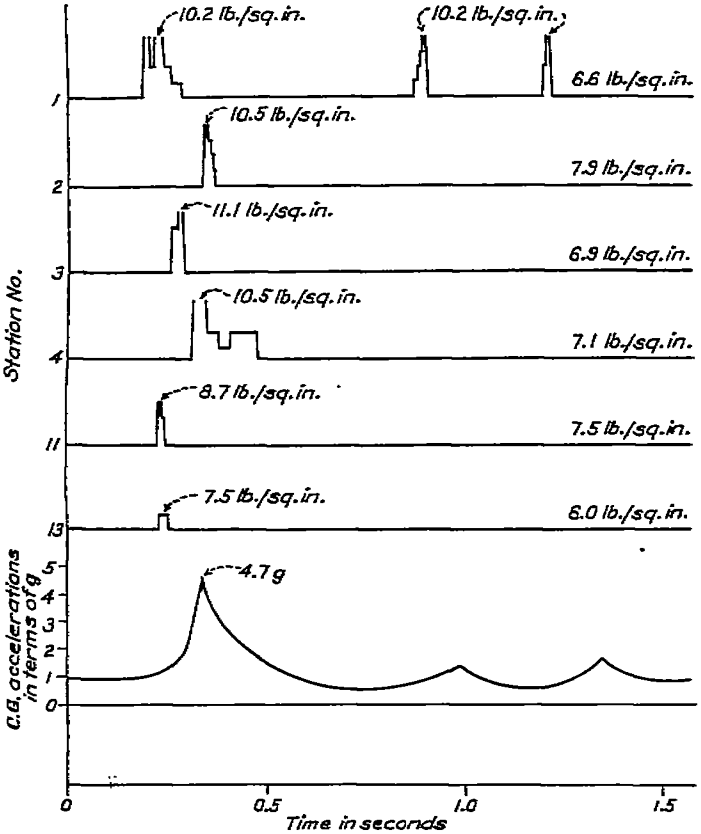

FIGURE 9.—Water pressure and vertical acceleration records in landing run 53 (pressures of 6 to 8 lb./sq. in. were not exceeded at other stations)

Wherever the water pressure exceeds the maximum recordable with the particular instrument adjustment used, the fact is indicated by discontinuing the record line for the time interval during which this pressure is exceeded. Figure 9 shows that pressures in excess of 6 to 8 pounds per square inch were concentrated near stations 2, 3, and 4 at the instant of maximum vertical acceleration. Figure 10 shows that even such small pressures as 2 pounds per square inch were also confined to practically the same region at the instant of maximum vertical acceleration. These are typical conditions, and illustrate the fact that a major portion of the total water reaction in landing can be considered as concentrated on a small part of the hull bottom. The fact that high pressure, as in Figure 9, exists simultaneously at stations 2 and 4 indicates a lag in the transverse distribution of pressure due to the dead rise of the V-bottom. In connection with these figures, it is also of interest to note the circumstances attending the principal landing shocks. In Figure 9, the acceleration record shows that the first was also the principal shock in landing. This landing was made from a steady glide without the usual leveling off immediately before making contact with the water. The acceleration record of Figure 10, however, shows

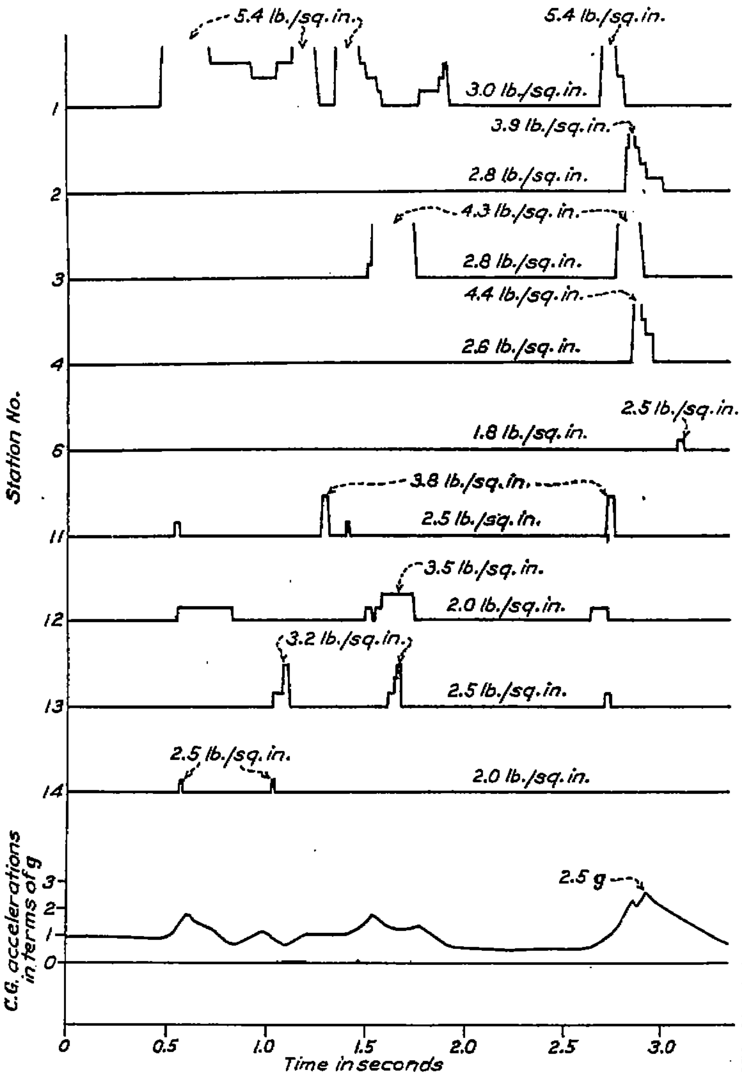

FIGURE 10.—Water pressure and vertical acceleration records obtained in landing run 90 (pressures of 2 to 3 lb./sq. in. were not exceeded at other stations)

a few slight shocks followed by a period during which the acceleration was appreciably less than $1g$ and ending with a considerable shock. The seaplane in this landing touched lightly, bounced off, settled again during the period of reduced acceleration and finally landed again with a shock as indicated by the final peak acceleration.

In the above discussion of Figures 9 and 10, it has been brought to attention that small as well as very high pressures are likely to exist on only a small part of the hull bottom at any given instant, particularly at the instant of maximum vertical shock. A study of all the records obtained during the tests shows that this is more or less true in every case. Pressures of about 3 pounds per square inch were found to be exceeded for periods longer than one-half second only at station 1. At stations 3, 4, 7, 12, and 13 pressures of this magnitude were constantly exceeded for periods ranging from one-fourth to one-half second at least once during the tests. At stations 2, 6, and 11 the longest duration for pressures of this magnitude was approximately one-tenth second. The stations showing these small pressures to be exceeded simultaneously are grouped as follows: (a) 1, 3, 11, 12, and 13; (b) 1, 2, 3, and 4; (c) 6 and 7. This shows that a large part of the entire water reaction can be regarded as acting on a comparatively small part of the total bottom area. It seems likely, however, that high pressures acting at stations 6 and 7 are accompanied by some small pressures on the area between these stations and the main step. Even a pressure of 1 or 2 pounds per square inch on this large area would exert a force which could not be neglected when considering total loads.

The time relation between water pressures and vertical accelerations indicates the pressure distribution which gives the greatest water reactions. As previously mentioned in connection with Figure 9, the maximum vertical acceleration ($4.7g$), in the landing to which that figure applies, occurred when the water pressure was high in the vicinity of stations 2, 3, and 4. This is typical of landings, but during take-offs in rough water the greatest vertical shocks may coincide with high pressures as far forward as stations 6 and 7. A specific case is run 68 in which the vertical acceleration was $3.0g$. It is evident, therefore, that large total loads may result from high local pressures near the step, as in landing, or from high pressures near the middle of the forebody, as they sometimes occur during take-offs. The data are not sufficient to show the actual load distributions for these two conditions. These can be approximated, however, as shown later in the discussion of total loads.

Accelerations.—The accelerations which were recorded simultaneously with water pressures are given in Table I, and some additional values in Table III. The greatest values recorded are $4.7g$ vertical, $0.9g$ longitudinal, and $0.6g$ lateral. This maximum vertical acceleration was recorded in a hard landing which resulted from descending at a steady glide without the usual leveling off immediately before landing. The greatest longitudinal accelerations usually occurred when planing in rough water, but the maximum given above occurred during a landing in large swells. Lateral accelerations were perceptible in cross-wind landings and sometimes during maneuvers in large swells. The maximum value as given above, however, was due to rotation about a submerged wing tip following the failure of a wing-tip float in a cross-wind landing. The greatest lateral acceleration due to shock was approximately $0.5g$. A comparison of vertical accelerations of the *C. G.* and the hull bottom shows that in the hull bottom the vertical acceleration is probably less than $2g$ greater than at the *C. G.*

A peculiarity of longitudinal accelerations is their reversal in direction. This action was most pronounced when planing in rough water with power full on. A peak deceleration indicating retarded motion was usually quickly followed by a peak acceleration of equal or slightly greater magnitude. This is probably due to the influence of two factors. The H–16 flying boat is a flexible structure in which nearly 50 per cent of the total weight lies outside of the hull. When the hull is suddenly retarded by a wave, the external structure strains forward and energy is thus stored in it. This energy is released quickly when the wave is passed, with the result that there is again a rapid relative motion between the hull and external structure. Since the weight of the hull is but little more than one-half the total weight of the seaplane, it appears reasonable to expect it would be accelerated forward an appreciable amount. In addition, the propeller thrust probably assists the forward acceleration materially because the water resistance of the hull momentarily drops to a small value at the instant the hull separates from the wave.

The first lateral shocks in cross-wind landings occurred in the expected direction, that is, they indicated that drift was retarded. It usually happened, however, that shocks occurred in the opposite direction before the seaplane came to rest. The seaplane appeared to skid around until it headed into the wind, due partially to the natural tendency to do so and partially to the pilot's use of the rudder. Experience showed that the danger of submerging a wing tip was considerably lessened by heading the seaplane into the wind before it settled into the water.

The records show that large, although not necessarily the maximum, longitudinal and vertical shocks occurred simultaneously. The vertical shocks accompanying the lateral shocks in cross-wind landings were usually small. In fact, the cross-wind landings were among the smoothest landings made. This probably was due to the pilot's caution in making these landings, and to the fact that waves were not met head-on. Although the lateral and vertical shocks in cross-wind landings were small, the likelihood of submerging a wing tip float made such landings risky.

Total loads.—The acceleration and pressure records indicate that the critical loads imposed on the seaplane were: (1) Vertical loads applied nearly under the *C. G.* in landings; (2) vertical loads applied near the middle of the forebody, due to the influence of waves in take-offs; (3) longitudinal loads in take-offs or landings in rough water; (4) lateral loads due to cross-wind landings.

The load distributions corresponding to the two vertical reactions mentioned above can be approximated by correlating the pressure and acceleration data. It is assumed that the total water reaction is equal to the weight of the seaplane multiplied by the vertical acceleration of the *C. G.*, and that this reaction is distributed as indicated by the water pressure data. This assumed magnitude of the total reaction may be in error due to two causes. Part of the water reaction is absorbed in the flexible structure, and the actual total reaction, therefore, is greater than that indicated by the acceleration. On the other hand, there may be a considerable portion of the weight of the seaplane borne by the wings, in which case the actual water reaction is less than the assumed. However, the wing-borne load will be something less than the weight of the seaplane, and the force absorbed in the structure is probably in the same order of magnitude. Since these two factors tend to nullify each other, the assumed total water reaction is considered to be reasonably accurate.

The distribution of the vertical load for the landing condition (fig. 11) is based on the maximum vertical acceleration of $4.7g$, and a concentration of high pressure on an area in the region of stations 2, 3, and 4. This conforms to the conditions shown in Figure 9. The magnitude of the pressure on this area is assumed to be the maximum pressure for this part of the hull bottom as given by the curves of Figure 8. A pressure of 4 pounds per square inch is assumed for the area between the high pressure region and the main step. This is indicated as a fair value by a study of the pressure likely to be sustained at station 1 under these conditions. The area of high pressure is considered to be a strip equally spaced on either side of a straight line joining stations 2 and 4. This line is inclined to the keel at an angle of approximately 30° and the pressure along it, as given in Figure 8, is about 11.5 pounds per square inch. The width of the strip and the dimensions of the area between it and the step are found by equating the load on the vertical projections of these areas to 4.7 W where W, the weight of the seaplane, is 10,000 pounds. The calculated width of the high pressure strip is 17 inches, its projected area on both sides of the hull is 22 square feet and the total load borne by it is 3.6 W. The remaining load of 1.1 W is due to the pressure of 4 pounds per square inch on an area of 20 square feet. In the diagram of this load distribution (fig. 11), the vertical components of normal pressures are shown.

The distribution of the vertical load for the rough water planing condition is shown in Figure 12. This distribution corresponds to a vertical acceleration of $3.0g$ and high pressure at stations 6 and 7. It was derived by a procedure similar to that used for the landing conditions. Since pressures were simultaneous at stations 6 and 7, the inclination of the high-pressure strip to the keel is determined by these two stations. This angle is again approximately 30°. The pressure is not uniform along the strip in this case, however. The maximum pressure curves of Figure 8 show that it varies along the 30° line from approximately 12.5 pounds per square inch at the keel to about 5 pounds per square inch at the chine. As the variation is assumed to be uniform, the average pressure is 8.75 pounds per square inch. Although pressures as small as 3 pounds per square inch were never found to be exceeded at any station simultaneously with high pressure at stations 6 and 7, it appears likely that there is some small pressure acting on the bottom between these stations and the main step. The assumption is made that a uniform pressure of 1.5 pounds per square inch acts on this large area. The dimensions of the high and low pressure areas are then found as in the previous case. The computed width of the high-pressure strip is 7.5 inches and its total projected area on both sides of the hull is 12 square feet. The load, due to the average pressure of 8.75 pounds per square inch on this area, is 1.5 W. The area subject to pressure of 1.5 pounds per square inch is 70 square feet and the corresponding load is 1.5 W.

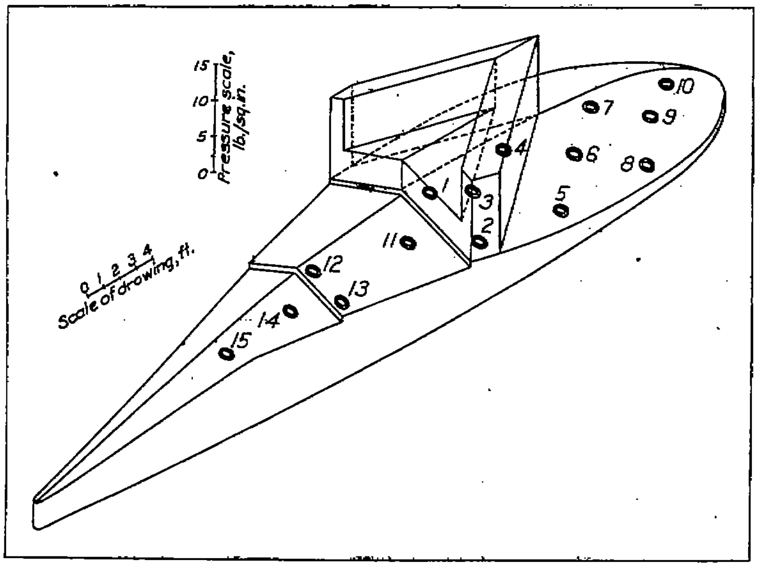

FIGURE 11.—Approximate distribution of the maximum vertical water reaction in landing. Total load=47,000 lbs. (4.7 times weight of seaplane)

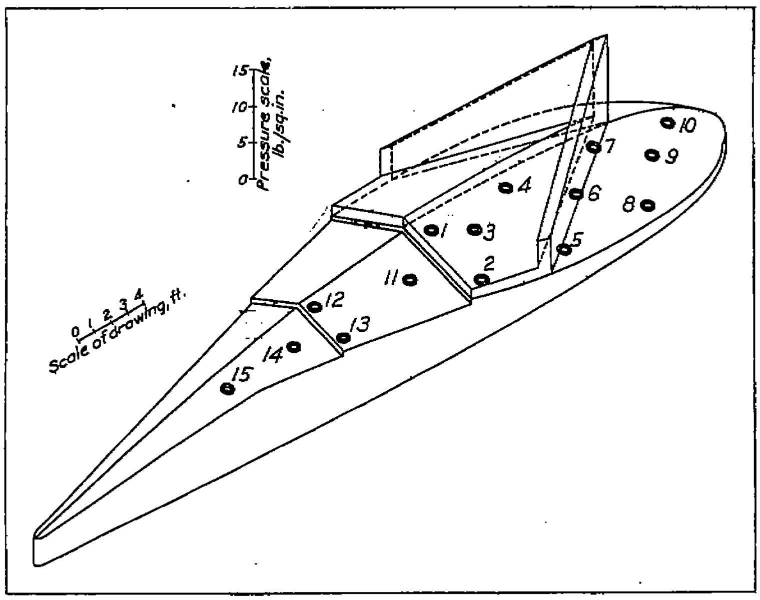

FIGURE 12.—Approximate distribution of a vertical load caused by impact with a wave in a take-off. Total load=30,000 lbs. (3.0 times weight of seaplane)

Comparison with previous results.—A comparison of the results of this investigation with those obtained in the two former investigations (references 1 and 2) shows that the distribution of maximum pressures on the forebody is similar on the H–16 and UO–1 seaplanes. The magnitude of the maximum pressure, however, is approximately twice as great on the H–16 as on the UO–1 and is 50 per cent greater than the maximum pressure on the TS–1. The distribution on the TS–1 is different than on either of the others, in that it lacks an appreciable transverse variation in pressure and shows very high pressures near the bow. The uniform distribution of pressures on the area between the steps of the H–16 is different than that on the afterbody of either of the float-type seaplanes, as they both showed increasing pressure toward the stern. In a previous investigation of water pressures on an H–16 hull (reference 6), pressures were found on the middle and forward parts of the forebody that compare well with the results given here. At the step, however, the pressures found were insignificant compared with those given here, which appears to be due to the lack of a complete investigation of the pressures in landings.

The large difference in maximum pressures on the H–16, TS–1, and UO–1 seaplanes may be due to one or several causes. The inclination of the keel line of the forebody (fig. 2) indicates the likelihood of high localized pressures near the keel at the main step as that is the lowest part of the bottom. The load per beam length might be considered an indication of the intensity of water pressure. The beam loads in thousands of pounds per foot of beam are 0.83 for the UO–1, 0.49 for the TS–1, and 1.00 for the H–16. It is evident that this basis of comparison is not valid unless the twin-float TS–1 is disregarded. Probably the most important reason for greatly different pressures on the different floats is that indicated by a recent analysis of the problem of maximum water pressures on seaplane floats when landing (reference 7). This analysis shows that the maximum water pressure, when landing, is a function of the V angle and the square of the vertical component of velocity. The V angle at the step of the H-16 is slightly greater than that of the UO-1 and about 5° greater than that of the TS-1. Therefore, this factor alone does not account for the difference in maximum pressures. It appears likely, however, that the rate of vertical descent of the H-16 is comparatively high since it has an immense number of external wires and struts, which probably offer enough resistance to make the ratio of lift to drag comparatively low. When the magnitude of the maximum water pressure is considered to vary directly as the square of the vertical velocity, it can be appreciated that a reasonable difference in the vertical speeds of two seaplanes will account for a large difference in maximum pressures.

The difference in the distribution of pressures on the afterbodies is due to the difference in the point of first contact with the water in landings. Both float-type seaplanes occasionally landed in such a manner that the stern hit the water first, whereas the main step was the first point of contact on the H-16 bottom. The presence or lack of an appreciable transverse variation in pressure appears to be dependent on the beam of the float. The most pronounced transverse variation is on the H-16 hull with a maximum beam of 10 feet; it is present on the UO-1 float with a beam of 40 inches; and is not appreciable on the TS-1 float with a beam of 26 inches. The high pressure near the bow of the TS-1 was due to a high rate of rotation resulting from high pressure on the stern in landing. The development of a retarding force in the form of a peak pressure so far forward, however, would seem to be due largely to the float shape. It is evident that this rotation will not develop when the seaplane lands with the first water contact near the *C. G.* as the H-16 does.

CONCLUSIONS

The results of this investigation lead to the following conclusions regarding the water pressures, accelerations, and total water loads experienced by the H-16 flying boat:

1. The greatest pressures occur in landings, and may be as great as 15 pounds per square inch near the keel at the main step.

2. Pressures as great as 11 pounds per square inch may occur at the keel slightly forward of the middle of the forebody during take-offs in rough water.

3. The area of the forebody subject to considerable pressure is roughly a triangle with its base at the step and its apex on the keel at the load water line forward. The maximum pressures on this triangle decrease in magnitude toward the bow and chines.

4. A pressure of 8 pounds per square inch may be experienced on nearly any part of the hull bottom between steps during landings.

5. A vertical acceleration of $4.7g$, which was once attained in a hard landing, is exceptional for either landings or take-offs. An acceleration of $3g$ is approximately the maximum for rough water take-offs and is not frequently exceeded in landings.

6. Although a maximum longitudinal acceleration of $0.9g$ was recorded in a landing in rough water, the greatest longitudinal accelerations usually occur during take-offs in rough water and in this condition $0.7g$ is frequently attained but not exceeded.

7. The maximum lateral acceleration likely to be attained in cross-wind landings is approximately $0.5g$, but the possibility of submerging a wing tip makes such landings dangerous.

8. The largest total loads usually occur during landings and are borne principally by an area close to the main step.

9. Waves may cause large total loads to be applied near the middle of the forebody during take-offs.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *December 4, 1929.*

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TABLE I

WATER PRESSURE DISTRIBUTION ON THE H-16 SEAPLANE HULL

Run No.	Maneuver	Condition of water	Air speed in m. p. h.	Average wind velocity in m. p. h.	Approximate water speed in m. p. h.	Longitudinal hull angle in degrees	Maximum accelerations during pressure runs in terms of g: Center of gravity, Vertical	Center of gravity, Longitudinal	Center of gravity, Lateral	Hull bottom, a	Hull bottom, b
93	Plowing	3 to 5 foot swells	26	0	26	4-9	1.2	−0.1			
95	do	do	25	0	25	3-10	1.2	−.1			
14	do	15 to 24 inch waves, choppy with swells	27-29	15	12-14			−.2			
15	do	do	25	15	10			0			
16	do	do	25	15	10			−.2			
17	do	do	25	15	10			−.2			
18	do	do	25	15	10			−.2			
32	Planing (normal)	2 to 3 foot waves, choppy	43	12	31	5-7	1.6	−.4			
33	do	do	41	12	29	3-6	1.0	−.2			
34	do	do		12		4-11	2.8	+0.5, −.7			
35	do	do	35-37	12	23-25	2-6	1.6	+.1, −.5			
36	do	do		12		2-5	1.2	−.4			
44	do	3-foot swells	32-37			3-8		+.1, −.4			
46	do	do	37-39			6-8					
55	do	15 to 20 inch waves	29	10	19	5-7	1.2	0			
56	do	do		10		3-4	1.2	0			
64	do	2 to 3 foot waves, choppy with swells	36-40	15	21-25			+.7, −.7		1.5	3.2
73	do	do	29-32	15	15		1.5	+.1, −.5		1.5	3.2
74	do	do	29-32	15	14-17		2.5	+.6, −.7		3.2	4.5
76	do	12-inch swells	40	10	30		1.2	+.1			
80	do	15 to 20 inch waves, choppy		13			1.5	+.1			
83	do	do	29	13	16		1.5				
85	do	3 to 5 foot swells	38-29	0	36-29	0-19		+.7, −.6	+0.1, −0.4	1.5	3.2
87	do	do	37	0	37		1.2	0			
91	do	do	36-38	0	30-38		1.4	+.1			
22	Planing (bow low)	12 to 18 inch chop with noticeable swells	44	11	33	1-2	1.4	+.2, −.4			
23	do	do	39	11	28	0-7	1.2	+.2, −.3			
24	do	do	45	11	34	0-5	1.3	+.4			
25	do	do	40-42	11	29-31	1-5	1.3	+.3			
38	do	12 inch waves	35-40	12	23-28	2-3	1.1	+.1, −.2			
39	do	do	37	12	25	0-6	1.2	+.3, −.4			
40	do	do	44	12	32	0-3		+.2, −.3			
57	do	15 to 20 inch waves	37-39	10	27-29	0-3	1.5	+.3			
58	do	do	35	10	25	0-7	1.5	0			
81	do	15 to 20 inch waves, choppy	47-45	13	34-32		1.5				
9	Getaway	15 to 24 inch waves, choppy with swells	44-47	15	29-32		1.1	−.3			
10	do	do	51	15	36		1.3				
11	do	do	50-54	15	35-39			−.4			
12	do	do	51-53	15	36-38			+.7, −.5			
13	do	do	61	15	46			+.2, −.4			
19	do	do	49-52	15	34-39			+.4, −.5			
30	do	2 to 3 foot waves, choppy	47-49	12	35-37	4-6	1.7	−.3			
37	do	do		12		0-10	2.1	+.5, −.7			
42	do	2 to 3 foot swells				7-14		+.3, −.8			
50	do	do	45-54			5-8		−.3			
54	do	15 to 20 inch waves	45-47	10	35-37	0-3	1.8	+.1			
66	do	2 to 3 foot waves, choppy with swells	48	15	33		3.3	+.2, −.5			
68	do	do	39-45	15	24-30		3.0	+.7, −.7		4.5	6.9
70	do	do		15			1.8	0			
72	do	do	42-45	15	27-30		2.6	+.2, −.9		1.5	4.5
82	do	15 to 20 inch waves, choppy	43	13	30		1.2	0			
89	do	3 to 5 foot swells	44-48	0	44-48		1.7			1.5	3.2
2	Landing	12 to 15 inch waves		17		7	1.5				
3	do	do		17		5	2.0	+.2, −.2			
4	do	do		17		7	1.4	+.1			
5	do	15 to 24 inch waves, choppy with swells	56-48	15	41-33		1.6	+.2			
6	do	do	55-50	15	40-35			+.3			
7	do	do	57-51	15	42-36			+.3			
8	do	do		15							
26	do	12 to 18 inch waves, choppy with swells	55-49	11	44-38		2.0	+.4			
27	do	do	54-51	11	43-40	9	1.3	+.1, −.1			
28	do	do	55-45	11	44-34	7	1.8	+.3			
29	do	2 to 3 foot waves, choppy	49-44	12	37-32	7	2.3	+.5			
31	do	do	49-42	12	37-30	8	1.7	+.2			
41	do	2 to 3 foot swells	48-36			8					
43	do	do				10					
45	do	do	47-32			11					
47	do	do	47-32			8		+.5			
49	do	do	46-29			9		+.4, −.4			
51	do	15 to 20 inch waves	52-41	10	42-31	8	2.8	+.4		1.5	3.2
53	do	do	50-36	10	40-26	8	4.7			3.2	6.9
60	do	do	52-41	10	42-31	7	2.3				
61	do	do	49-36	10	39-26	7	3.4			3.2	4.5

Minus accelerations indicate accelerating forces acting forward or to the left.
a = Pressure or acceleration exceeded.

TABLE I—Continued

WATER PRESSURE DISTRIBUTION ON THE H-16 SEAPLANE HULL—Continued

Recorded water pressures in pounds per square inch — Pressure stations

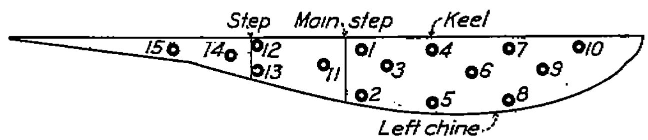
1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		Remarks	Run No.
a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b		
	7.5		7.4		7.0		6.9		7.6		6.6		7.2		7.2		6.0		6.9		4.0		3.7		3.1		3.5			Running parallel with swells.	93
	7.7		7.6		7.3		7.2		7.9		3.8		4.1		4.2		3.4		3.7		4.7		4.3		3.7		4.1			Do.	95
	6.6		6.4		6.1		6.1		6.5	5.1	6.2		5.3		5.4		5.1				6.1		6.5				6.1		5.7		14
	3.1				2.9		2.7		3.3		1.8		2.3		2.4		2.1		1.9		3.0		3.7		2.8		3.0		2.8		15
	5.4		5.2		5.0		5.0		5.4		2.7		3.2		3.2		2.9	3.2	3.7		3.8		4.5		3.6		3.9		3.6		16
	6.4		6.2		5.9		5.9		6.4		3.7		4.1		4.1		3.3		3.8		5.2		5.7		4.8		5.2		4.1		17
	6.9		6.7		6.4		6.4		6.8		5.4	5.7	6.7		5.7		5.5		5.5		6.3		6.6		5.9		6.3		5.8		18
5.2				3.2	4.0	4.0			2.8		1.4		2.0		2.1		1.7		1.5		2.4		2.9		2.2		2.1		2.1		32
	6.7				6.5		6.6		7.2		5.7		6.0		6.1		6.0		5.8		6.3		6.7		5.8		6.2		5.7		33
5.2		2.9	3.4	4.0		4.0			2.8	2.8	3.2	3.8			2.6		2.2		2.1		2.9		3.6		2.8		2.8		2.6		34
5.1					5.0		4.9		5.4	5.2	5.9	6.9			4.4		4.1		4.0		3.5		4.2		3.3		3.4		3.2		35
	4.9				4.7		4.7		5.3		3.5		3.9		4.1		3.8		3.8		3.7		4.4		3.5		3.6		3.3		36
					7.3	8.1	9.8		8.0		5.9		6.2		6.4		6.3		6.1		7.0		7.3		6.4		6.9		6.2		44
6.3		3.7		5.2		5.1			3.7		2.5		3.1		3.2		2.9								3.1		3.2		3.0		46
	6.8		8.1		7.2		7.3		7.9		6.2		6.6		6.6		6.7		6.4		7.0		7.0		6.0		6.2				55
	6.6		8.0		7.0		7.1		7.8		6.5		6.9		7.0		7.0		6.7		6.0		6.2		5.2		5.5				56
	8.0		8.2		7.5	7.6	8.6		8.2	8.9		6.8	7.6		6.9		6.1		6.2		5.7		5.2		4.5		4.9				64
	7.3		7.6		6.8		6.8		7.4		6.2	6.8	7.6		6.8		6.1		6.1		5.9		5.2		4.6		5.0				73
	7.1		7.3		6.7	6.7	7.6		7.3	8.6	9.3	7.1	7.9		7.1		6.3		6.5		5.1		4.6		4.0		4.3				74
	7.6		7.7		7.2		6.9		7.7		5.3		5.8		5.9		4.9		5.4		6.4		5.9		5.1		5.6				76
	6.8		7.2		6.7		6.7		7.3		6.3		6.9		6.9		5.8		6.5		5.9		5.4		4.6		5.0				80
	2.8		2.8		2.6		2.4		2.8		1.5		1.6		1.7		1.2		1.0		3.5		3.0		2.5		2.8				83
7.9	12.0		7.8	9.8	11.4	8.3	9.8		6.0	8.3	9.2	6.7	7.3		6.6		5.6		6.3		7.3		7.1		6.0		6.7			Attempted take-off perpendicular to swells. Failed due to violent pitching.	85
	7.9		7.8		7.4		7.3		8.0		6.4		7.1		7.0		5.9		6.7		7.3		7.1		6.0		6.7			Running parallel with swells	87
	6.8		6.7		6.4		6.2		6.9		5.8		6.4		6.4		5.3		6.0		5.9		5.5		4.7		5.2			Do.	91
					6.7				7.1		5.9	9.8			6.1		5.8		6.0		6.5		6.8		6.0		6.6		6.0	Porpoising develops in this maneuver.	22
						3.4	4.2		3.0	2.6		2.9			2.1		1.7		1.6		2.7		3.3		2.5		2.6		2.5		23
					4.7		4.6		5.2	3.8		4.3			2.9	3.9							4.2		3.3		3.5		3.3		24
					6.1		6.1		6.5	4.6	5.2	4.1	4.9		4.2		4.0		4.0		4.7		5.3				4.7		4.4		25
					6.6		6.6		7.2	7.3	8.1	7.5	9.3		6.5		5.8		5.8		5.9		6.3		5.4		5.8		5.3		38
	6.7				6.5		6.5		7.2		6.9	6.2	7.3		6.3		5.7		5.7		5.0		5.6		4.7		5.0		4.5		39
	3.1				3.0		2.9		3.4	2.4	2.8	3.4			2.3		1.9		1.7		2.9		3.4		2.7		2.7		2.5		40
	6.1		7.3		6.4		6.6		7.2	6.3	7.6	10.8			6.9		6.8		6.5		7.0		7.0		6.0		6.2				57
	6.4		7.7		6.7		6.9		7.6	6.2	7.5	10.7			6.6		6.7		6.4		6.5		6.5		5.7		6.0				58
	7.5		7.6		7.1		7.1		7.7		6.0	6.5	7.2		6.5		5.4		6.1		6.6		6.1		5.2		5.7				81
					6.8				7.2		6.0		6.3		6.3		6.1		6.2		7.2		7.3		6.7		7.3		6.6		9
2.9	3.8			2.7	3.2				3.2	1.9	2.4	3.6			2.5		2.2		2.0				3.5		2.6		2.8		2.6		10
	5.2				4.9		4.8		5.3	4.1		4.5			3.0		2.8		2.7		5.2		5.7		4.8		5.2		4.8		11
	7.4				6.9		6.9		7.3	3.8		4.2	4.9		4.2		3.9		3.9				5.4								12
					2.5		2.3		2.9		1.6	3.1			2.2		1.9		1.7		2.6		3.3				2.6		2.4		13
5.3	6.5		3.9	3.8	4.3				4.3	4.7		5.3			3.4		3.2		3.1		3.5		4.2		3.3		3.5		3.3		19
9.0	10.0				6.4		6.4		7.1		5.5		5.8		5.9		5.8		5.7		6.2		6.7		5.8		6.2		5.6		30
					6.5		6.5		7.2	8.7		10.0			6.3		6.2		5.7		6.2		6.6		5.7		6.1		5.6	Held bow low until a wave forced it up and boat jumped off.	37
				7.9	9.1	7.5	9.1		7.4	8.2	9.1	7.5	9.3		6.6		6.5		6.4		6.8		7.2		6.2		6.7		6.1		42
10.5			7.3		6.8		6.8		7.4		5.7		6.0		6.2		6.0		5.9		5.3		5.8				5.2		4.7	Skimmed crest of a swell.	50
	6.8		8.1		7.1		7.3		8.0		6.0	7.4	9.3		6.5		6.5		6.2		6.0		6.2		5.2		5.5				54
7.2	8.1		6.0	6.7	7.4	7.4	8.2		6.9		6.4		6.9		7.0		6.2		6.3		5.9		5.4		4.6		5.0				65
7.1	8.8		7.3		6.7		6.7		7.3	7.8	8.4	7.2	9.3		6.4		5.7		5.8		6.8		6.2		5.4		5.8				68
4.1	4.8		3.1	3.4	3.7	3.7	4.4		3.0		2.2		2.4		2.4		2.1		1.9		3.0		2.7	2.1	2.7		2.5				70
7.1	8.6		7.2	6.5	8.0	7.5	8.8		7.1	8.3	8.9	7.6	9.7		6.8		6.1		6.1		5.2		4.7		4.0		4.4				72
	7.4		7.5		7.0		6.9		7.5		5.8	6.2	7.0		6.2		5.2		5.9		6.2		5.8		5.0		5.4				82
5.1			2.7		2.6		2.4		2.9		1.7		1.9		2.1		1.5		1.1	3.4	3.9		3.1		2.4		2.8			Running parallel withswells.	89
7.1	8.4		5.4	7.0	7.9	5.8	6.9		5.6		4.7		4.9		4.9		4.7		4.8		5.0		5.5		4.7		5.0		4.6		2
4.5		3.0		4.0		3.5	4.2		3.0		2.2		2.4		2.6		2.4		2.2		2.0		2.0	1.9	2.5		1.9		1.9		3
9.1	10.5		6.9	6.6	7.6		6.6		7.1		5.8		6.0		6.0		5.8		5.9		5.6		6.0		5.2		5.5		5.0		4
9.1	10.3		6.9	7.6	8.9	7.4	8.8		7.1		5.7		6.0		6.1		5.8		5.9		6.9		7.2		6.4		7.0		6.4		5
4.7				3.7		3.1	3.9		2.9		1.9		2.3		2.3		2.1		1.9		2.6		3.2	2.4	3.2		2.5		2.4		6
				6.1	7.0	6.0	7.2		5.1		2.6		3.0		3.1		2.8		2.7		4.0		4.7		3.8		4.0		3.7		7
											3.7		4.1		4.1		3.8		3.8		4.6		5.2		4.4		4.6		4.3		8
8.2						7.9	9.1		6.4		3.9		4.1		4.2		4.0		4.0		4.8		5.4		4.5		4.8		4.5		26
					6.3		6.2		6.8		5.0		5.3		5.3		5.0		5.1		6.2		6.5		5.7		6.1		5.6		27
				2.6					2.3		1.3		1.8		2.0		1.6		1.5	3.1		3.0	3.5	2.0	2.7		2.2		2.0		28
6.7				8.8	10.1	8.8	9.9		7.2		5.6		5.9		6.0		5.9		5.8		6.0	6.4	6.8		5.5		5.9		5.4		29
				4.0			2.4		2.8		1.4		2.0		2.1		1.7		1.5		2.9		3.6	2.8	3.4		2.8		2.6		31
9.3				7.6	8.8	8.9	10.0		7.2		5.6		5.9		6.0		5.9		5.8		6.4	6.9	7.3	5.9	7.4		6.4		5.8		41
				7.9	9.1	9.1	10.2		7.4			7.2	8.9		6.3		6.2		6.1		5.6		6.1	5.2	6.5		5.6		5.1		43
5.6		3.3		4.4		4.5														3.1	4.0	3.6	4.3	2.7	3.3		2.7		2.5		45
9.4				7.8	9.1	6.5	7.8		6.5		5.4		5.8		5.9		5.8		2.8	3.4	3.7	4.1	4.3	3.2	4.0		3.4		3.1		47
				5.4	6.1	4.9	6.1		5.0		3.5		3.9		4.0		3.8		3.7												49
9.3			7.2	8.8	10.1	8.7	9.8		7.1		5.7		6.1		6.1		6.2		5.9		7.2		7.5		6.2		6.7				51
10.2		10.5		11.1		10.5			7.8		6.2		6.5		6.6		6.7		6.3	7.5	8.7		7.0	6.0	7.5		6.2			Very hard.	53
9.4			7.3	10.3		7.3	8.7		7.2		5.9		6.3		6.4		6.4		6.1	6.0	6.7		6.2		5.2		5.5			Boat came up by bow and down hard.	60
10.1			7.8	9.5	11.9	9.3	10.4		7.7		6.2		6.6		6.6		6.7		6.4		7.2		7.5	6.2	7.7		6.7			Boat came up by bow and bounced clear.	61

b = Pressure or acceleration not exceeded.

WATER PRESSURE DISTRIBUTION ON THE H-16 SEAPLANE HULL—Continued

Run No.	Maneuver	Condition of water	Air speed in m. p. h.	Average wind velocity in m. p. h.	Approximate water speed in m. p. h.	Longitudinal hull angle in degrees	Maximum accelerations during pressure runs in terms of g				
							Center of gravity			Hull bottom	
							Vertical	Longitudinal	Lateral	a	b
63	Landing	2 to 3 feet waves, choppy with swells	50-38	15	35-23		3.1	+0.4, −0.5		1.5	3.2
65	do	do		15						1.5	4.5
67	do	do	49-45	15	34-30			+.5, −.3		3.2	4.7
69	do	do		15			2.3	+.6, −.5		3.2	4.5
71	do	do		15			1.9	+.4, −.4			
75	do	12-inch swells	49-39	10	39-29	8	2.6			3.2	4.5
77	do	do	52-41	10	42-31		1.9	+.4, −.3		1.5	3.2
78	do	6-inch chop	53-43	10	43-33		1.4	+.1			
79	do	15 to 20 inch waves, choppy	43-39	12	35-26		2.0	+.4, −.2		1.5	3.2
84	do	3 to 5 feet swells	49-39	0	49-39	10		+.3, −.3	−0.2	1.5	3.2
86	do	do		0		10			0	1.5	3.2
88	do	do	49-40	0	49-40	8	2.3		−.1	1.5	3.2
90	do	do	48-34	0	48-34	8	2.5	+.5	+.2	1.5	3.2
92	do	do	48-40	0	48-40	9	2.4		−.2	3.2	4.5
59	Cross-wind landing, wind on right	15 to 20 inch waves	50-48	10	50-48	9					
62	do	do	50-34	10	50-34	8	2.9	+.2	−.6	1.5	3.2

Minus accelerations indicate accelerating forces acting forward or to the left.
a = Pressure or acceleration exceeded.



WATER PRESSURE DISTRIBUTION ON THE H-16 SEAPLANE HULL—Continued

Recorded water pressures in pounds per square inch — Pressure stations																														Remarks	Run No.
1		2		3		4		5		6		7		8		9		10		11		12		13		14		15			
a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b		
10.3	11.8		7.7	6.7	8.5	7.9	9.4		7.6		6.3		6.8		6.9		6.1		6.2		6.1		5.5	4.8	5.7		5.2				63
10.7	12.2	8.0	9.7	8.9	9.8	8.2	9.7		7.9	8.6		7.3	9.4		6.5		6.8		6.0	6.6	8.2		5.3	4.6	5.4		5.0				65
10.5	11.9		7.9	9.7		9.6	10.3		7.7		5.0		5.4		5.5		4.8		4.8		6.3		5.8		5.0		5.8				67
4.7		3.8		3.7		4.3			2.9	2.1	2.8		1.7		1.6		1.3		1.1	2.2	2.5		1.9	1.4	1.8		1.6				69
10.5	11.9		7.9		7.1	9.6	10.3		7.7		4.9		5.8		5.3		4.7		4.7		6.2		5.7	5.0	5.9		5.3				71
12.3			7.5	9.3		10.0			7.5		5.6		6.0		6.1		5.0		5.7		6.1		5.7	4.9	5.9		5.3				75
11.1	12.3		7.5	9.3		9.1	10.0		7.5		6.0		6.5		6.5		5.4		6.1		6.2		5.7		4.9		5.3				77
11.1	12.3		7.5		6.9		6.8		7.5		5.8		6.2		6.2		5.2		5.9		6.0		5.5		4.7		5.2				78
10.3	10.6		7.0		6.5	8.8	9.5		7.1		5.6		6.0		6.1		5.0		5.7		6.7		6.2		5.3		5.9				79
12.6			7.3	9.3	10.7	9.3	10.0		7.5		5.9		6.5		6.5		5.5		6.1		6.5		6.2		5.3		5.9				84
13.7			8.0	10.2	11.8	10.9			8.2		6.2		6.8		6.8		5.7		6.4		7.7	7.2	9.3		6.2		6.9				86
12.0	13.1		7.6	8.7	9.5	8.2	9.7		7.8		6.2		6.8		6.8		5.7		6.4		7.0		6.7		5.8		6.4				88
5.4		3.9		4.3		4.4			3.0	1.8	2.5		1.9		2.1		1.6		1.5	3.0	3.8	2.1	3.5	2.6	3.2	2.0	2.5			Sharp lateral blow on stern after pressure run.	90
13.5			7.8	10.0	11.5	8.5	10.0		8.0		6.6		7.2		7.2		6.0		6.9		6.7		6.4		5.4		6.0				92
9.6			7.5		6.6		6.8		7.4		5.9		6.3		6.4		6.5		6.2	6.7	7.7		6.2		5.2		5.5				59
2.7		2.7		3.1		3.2			2.1	1.1	1.6	2.9			1.8		1.6		1.3	3.2	3.7	4.0		3.0	3.7	2.5	2.7			Demolished left wing tip float and "ground looped."	62

b = Pressure or acceleration not exceeded.

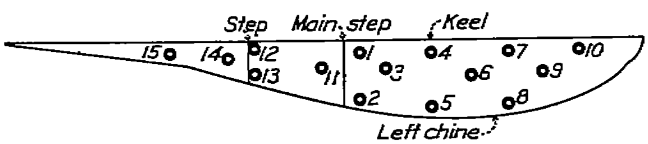


TABLE II

SUMMARY OF HIGHEST PRESSURES

(a) Five Highest Pressures in Landings

Pressure stations																													
1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*	Run No.	*P*
86	14.5	53	11.3	53	11.9	86	11.7	----	----	65	9.4	65	8.6	----	----	----	----	----	----	53	8.4	36	8.5	61	7.2	62	2.9	----	----
92	14.3	65	9.1	86	11.8	53	11.3	----	----	69	2.7	43	8.3	----	----	----	----	----	----	65	7.7	41	7.4	53	7.0	90	2.5	----	----
84	13.4	90	4.7	60	11.1	75	10.8	----	----	90	2.4	62	3.7	----	----	----	----	----	----	59	7.5	29	6.9	41	6.9	----	----	----	----
75	13.1	69	4.6	92	11.0	71	10.2	----	----	62	1.6	----	----	----	----	----	----	----	----	60	6.7	62	4.7	43	6.1	----	----	----	----
88	12.8	45	4.1	61	11.0	67	10.2	----	----	----	----	----	----	----	----	----	----	----	----	47	8.8	47	4.5	71	5.7	----	----	----	----

(b) Five Highest Pressures in Taxying

50	11.3	48	4.5	85	10.9	85	9.3	----	----	64	9.7	57	11.6	----	----	24	4.7	16	3.7	89	3.9	----	----	70	2.7	----	----	----	----
85	10.2	34	3.4	42	8.8	44	9.2	----	----	37	9.5	58	11.5	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
30	9.8	----	----	72	7.5	42	8.6	----	----	74	9.2	37	10.8	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
68	8.2	----	----	66	7.3	64	8.4	----	----	85	9.0	22	10.6	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
66	7.9	----	----	46	6.0	72	8.4	----	----	72	8.9	72	8.9	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

P=Mean pressure corrected for acceleration in lb. per sq. in. Correction is +¼ lb. per sq. in. (See text.) Blank spaces indicate that pressures which units were set to record were not exceeded.

TABLE III

MAXIMUM ACCELERATIONS NOT SIMULTANEOUS WITH WATER PRESSURE RECORDS

Run No.	Maneuver	Condition of water surface	Wind velocity in m. p. h.	Acceleration at the *C. G.* in terms of *g*		
				Vertical	Longitudinal	Lateral
3	Landing	12 to 15 inch waves	17	2.4		
94	do	3 to 5 foot swells	0	2.2	0.9, −0.7	
37	Getaway	2 to 3 foot waves, choppy	12	2.5		
34	Normal planing	do	12	3.1		
35	do	do	12	2.3	.8, −.9	
36	do	do	12	1.7	.2, −.5	
24	Planing with bow low	12 to 18 inch chop with noticeable swells	10 to 12		−.7	
25	do	do	10 to 12	1.4	−.5	
40	do	12-inch waves	12	1.4		
81	do	15 to 20 inch waves, choppy	18		−.7	
96	Landing cross wind (wind on right)	12 to 15 inch waves	7	2.1	.7, −.3	0.1, −0.2
99	Landing cross wind (wind on left)	do	7	2.0	.3	−.3, .2
101	Landing cross wind (wind on right)	15-inch waves	11 to 17	2.0	.5	.2, −.5
102	do	do	11 to 17	3.5	.3	.2, −.4
104	do	12 to 15 inch waves, choppy	11 to 17	2.3	.3	.3, −.3
105	do	do	11 to 17	1.8		.2, −.2
106	Landing cross wind (wind on left)	do	11 to 17	2.2	.3	−.4, .1

Minus accelerations indicate accelerating forces acting forward or to the left.